



Standard Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing¹

This standard is issued under the fixed designation E428; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice covers a procedure for fabrication and control of metal alloy reference blocks used in ultrasonic examination that have a flat-surface sound entry, are cylindrical in shape, and contain flat-bottom holes (FBH) which may be used for checking the performance of ultrasonic examination instrumentation and search units and for standardization and control of ultrasonic examination of metal alloy products. The reference blocks described are suitable for use with either the direct-contact method or immersion pulse-echo ultrasonic methods.

NOTE 1—Use of flat-surface reference blocks may not be suitable for cylindrical materials (1)².

1.2 While this procedure is basically designed for the fabrication and control of carbon and alloy steel blocks to be used in conjunction with the examination of these materials, the fabrication and control procedures may also be suitable for the preparation of blocks for other types of materials such as nickel-base alloys, certain types of aluminum alloys, and so forth. Additional procedures and controls may be required when fabricating reference blocks from other than carbon or alloy steel material. This practice shall in no way preclude the specification or addition of any supplemented requirements as deemed necessary for the specific application. This practice, however, must not be confused with, nor does it supersede Practice E127, specifically governing the fabrication and evaluation of 7075-T6 aluminum alloy ultrasonic standard reference blocks.

NOTE 2—Practice E127 and Guide E1158 also describe procedures for selecting material, fabricating blocks, and checking response. Unlike this practice, Practice E127 has requirements for evaluation relative to a specified standard target.

¹ This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Method.

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² The boldface numbers in parentheses refer to the list of references at the end of this standard.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:³

E127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks

E1158 Guide for Material Selection and Fabrication of Reference Blocks for the Pulsed Longitudinal Wave Ultrasonic Testing of Metal and Metal Alloy Production Material

E1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, see Terminology E1316.

4. Summary of Practice

4.1 This practice details a basic fabrication and control procedure and defines the minimum requirements to be met in matching carbon and alloy steel reference blocks with the material to be examined. Additional supplemental requirements may be needed when using this practice to fabricate reference blocks from other types of materials or with larger diameter holes. The physical characteristics of the hole may be established by evaluating plastic replicas. It must be recognized however that there are limitations on the size hole that may be replicated and evaluated.

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

5. Significance and Use

5.1 Reference blocks fabricated in accordance with this practice will exhibit specific area-amplitude and distance-amplitude relationships only with an immersion test at 5 MHz using the search unit, test instrument and test parameters described in this practice. Comparison test at other frequencies or with uncalibrated instruments will not necessarily give the same relationships shown in this practice. See Reference (2) for area-amplitude limitations at other frequencies and transducer diameters. Also see Reference (3) for cautions regarding use of standard blocks for test standardizations.

6. Material Selection

6.1 The material to be used for reference blocks should be similar in its acoustic attenuation to the material which is to be examined. The grain size, heat treat condition, physical and chemical composition, surface finish, and manufacturing procedure (rolling, forging, and so forth) are variables to be considered in matching acoustic responses.

6.1.1 The general evaluation procedure shall be to introduce a longitudinal pulse-echo beam into either side of the block on the axis to be used for determining metal-path distance. An immersion examination method using clean water as a couplant or, a contact method using appropriate couplant (oil, glycerin, and so forth) is satisfactory. The examination instruments, frequency, and search unit used in the evaluation of the raw material intended for the fabrication of the reference blocks shall be comparable to that used in the examination of the production material.

6.1.2 The material used for reference blocks shall be 100 % scanned while the examination system is adjusted to display, whenever possible, an acoustic noise level from the material of 20 % of full-scale deflection (FSD). In cases of materials that are acoustically transparent to the extent that this requirement cannot be satisfied, a readable acoustic noise level shall be displayed. The acoustic noise level from the material is not to be confused with inherent electrical instrument noise often observed when the system sensitivity is adjusted to its maximum level range.

6.1.3 The material used for reference blocks shall be free of discrete ultrasonic discontinuity indications greater than twice the amplitude of the noise level displayed in accordance with the requirements of 6.1.2.

6.1.4 Attenuation shall be checked by comparing multiple reflections from the back surface of the test block material with that of the material to be examined. With the amplitude from the first back reflection adjusted to 90 % of FSD, the sum of the amplitude of the first three back reflections from both samples shall compare within ± 25 % or as required by the application. On samples that are to have FBHs smaller than $\frac{3}{64}$ in. (1.2 mm) in diameter, the decay patterns shall compare within ± 10 % or as required by the application.

6.1.5 Lowering the examination frequency tends to minimize discernible differences in response. At 1.0 MHz, a large group of materials may be acoustically penetrable with relatively similar results and may satisfy the requirements of 6.1.4. At frequencies such as 5.0 MHz and higher, microstructure

changes usually yield readily discernible differences in acoustic response and restrict the applicability of reference blocks.

7. Fabrication Procedure

7.1 Unless otherwise specified, select the blocks to be made from those listed in Table 1. Block sets conforming to customary commercial practice are grouped as follows:

- 7.1.1 Distance-Amplitude Response (D/A),
- 7.1.2 Area-Amplitude Response (A/A), and
- 7.1.3 Basic (selected from D/A and A/A groups).

7.2 All blocks are to be fabricated in accordance with Fig. 1. Dimension “A” (metal travel) and Dimension “D” (FBH diameter) are given in Table 1; Dimension “E” (block length) is derived. The following machining sequence is recommended:

NOTE 3—This practice may be used to produce blocks with flat-bottom holes of a larger diameter than described. Utilization of larger flat-bottom holes shall be by agreement of the using parties.

7.2.1 Machine all blocks to a uniform 32 rms finish and to the required dimensional tolerances.

7.2.2 Drill the test hole to the nominal $\frac{3}{4}$ -in. (19.0-mm) depth with a standard drill point.

7.2.3 Carefully prepare a flat-bottom drill or cutter with cutting edges square and flat within 0.0005 in. (0.013 mm) and perpendicular to its longitudinal axis (flatness, squareness, etc., should be checked at a minimum of 60 \times magnification on an optical comparator).

7.2.4 Continue to drill as needed to remove all the conical configuration of the bottom of the hole.

7.2.5 Remove drill, check cutting edge, regrind, if necessary.

7.2.6 Remove an additional 0.005 in. (0.13 mm) of material from the hole bottom.

7.2.7 Recheck cutting edges of the drill on the optical comparator, regrind, if necessary, and repeat 7.2.5 and 7.2.6. Careful attention must be given to the squareness of corners of the cutter, the slightest radius reduces the reflective area of the hole bottom.

8. Checking Physical Characteristics

8.1 All dimensions of the reference blocks including the diameter and perpendicularity of the examination hole may be checked by normal quality control procedures for physical measurements. The configuration, squareness, flatness, and surface finish for hole bottoms $\frac{3}{64}$ in. (1.2 mm) in diameter and larger may be checked by the following recommended technique for making and evaluating plastic replicas:

8.1.1 Clean hole with a suitable oil-free noncorrosive solvent and dry with a stream of dried and filtered air.

8.1.2 Mix the replicating material in accordance with the manufacturer’s instructions.

8.1.3 Force the material into the hole with a disposable medical syringe and needle of adequate size.

8.1.4 Fill the hole beginning at the bottom and gradually moving outward making certain that no air pockets or bubbles remain in the hole.

TABLE 1 Standard Block Sizes and Recommended Block Sets

NOTE 1—Material to be as specified by the user.

NOTE 2—All dimensions and tolerances are to be in accordance with Fig. 1.

NOTE 3—1 in. = 25.4 mm.

NOTE 4—Block sets shown are typical of established commercial practice; more or fewer blocks may be required for specific applications.

Metal Travel and Designator			Distance/Amplitude, 19 in each set			Basic Set, 10 Total			Area/Amplitude Set, 8 Total							
Nominal MT	Dim. "A"		Desig.	3	5	8	3	5	8	Diameter of Flat-Bottom Holes (1/64 in./1.6 mm) Dimension "D"						
	(in.)	(mm)								1	2	3	4	5	6	7
0.063	0.0625	1.6	-0006	3	5	8	...	...	...	...	...	...	...	...	...	...
0.125	0.125	3.2	-0012	3	5	8	...	5	...	...	...	...	...	...	...	...
0.250	0.250	6.4	-0025	3	5	8	...	5	...	...	...	...	...	...	...	...
0.375	0.375	9.5	-0038	3	5	8	...	...	...	...	...	...	...	...	...	...
0.500	0.500	12.7	-0050	3	5	8	...	5	...	...	...	...	...	...	...	...
0.625	0.625	15.9	-0062	3	5	8	...	...	...	...	...	...	...	...	...	...
0.750	0.750	19.1	-0075	3	5	8	...	...	...	...	...	...	...	...	...	...
0.875	0.875	22.2	-0088	3	5	8	...	...	...	...	...	...	...	...	...	...
1.000	1.000	25.4	-0100	3	5	8	...	...	...	...	...	...	...	...	...	...
1.250	1.250	31.8	-0125	3	5	8	...	...	...	...	...	...	...	...	...	...
1.500	1.500	36.1	-0150	...	...	...	...	5	...	...	...	...	...	...	...	...
1.750	1.750	44.5	-0175	3	5	8	...	...	...	...	...	...	...	...	...	...
2.000	2.000	50.8	-0200	...	...	...	...	...	...	...	...	...	...	...	...	...
2.250	2.250	57.2	-0225	3	5	8	...	...	...	...	...	...	...	...	...	...
2.500	2.500	63.5	-0250	...	...	...	...	...	...	...	...	...	...	...	...	...
2.750	2.750	69.9	-0275	...	...	...	...	...	...	...	...	...	...	...	...	...
3.000	3.000	76.2	-0300	3	5	8	3	5	8	1	2	3	4	5	6	7
3.250	3.250	82.6	-0325	3	5	8	...	...	...	...	...	...	...	...	...	...
3.500	3.500	88.9	-0350	...	...	...	...	...	...	...	...	...	...	...	...	...
3.750	3.750	95.3	-0375	3	5	8	...	...	...	...	...	...	...	...	...	...
4.000	4.000	101.6	-0400	...	...	...	...	...	...	...	...	...	...	...	...	...
4.250	4.250	106.0	-0425	3	5	8	...	...	...	...	...	...	...	...	...	...
4.500	4.500	114.3	-0450	...	...	...	...	...	...	...	...	...	...	...	...	...
4.750	4.750	120.7	-0475	3	5	8	...	...	...	...	...	...	...	...	...	...
5.000	5.000	127.0	-0500	...	...	...	...	...	...	...	...	...	...	...	...	...
5.250	5.250	133.4	-0525	3	5	8	...	...	...	...	...	...	...	...	...	...
5.500	5.500	139.7	-0550	...	...	...	...	...	...	...	...	...	...	...	...	...
5.750	5.750	146.1	-0575	...	...	...	...	...	...	...	...	...	...	...	...	...
6.000	6.000	152.4	-0600	3	5	8	...	5	8	...	...	...	...	...	...	...
6.250	6.250	158.8	-0625	...	...	...	...	...	...	...	...	...	...	...	...	...
6.500	6.500	165.1	-0650	...	...	...	...	...	...	...	...	...	...	...	...	...

8.1.5 Insert a small wire, pin, needle, or other suitable object that will serve as a rigid core and facilitate removal of the replica.

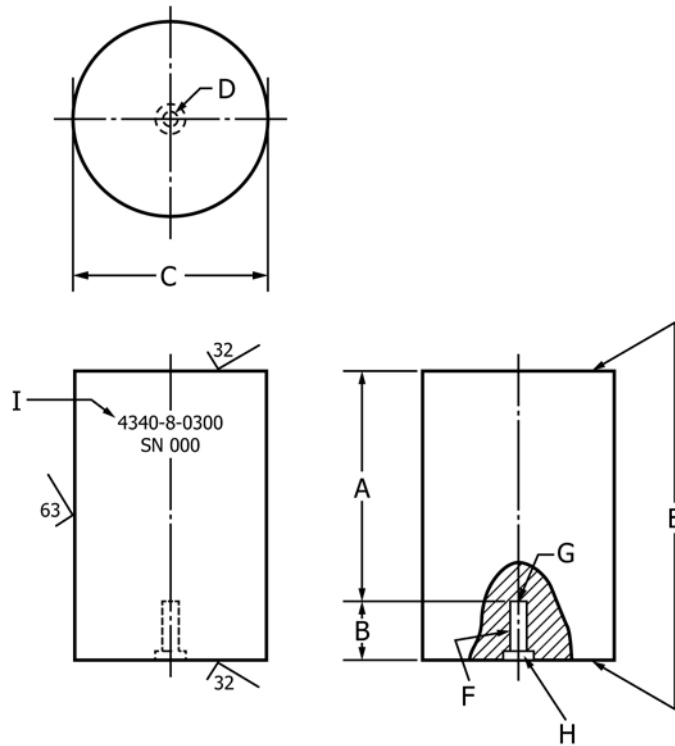
8.1.6 After curing, the replica may be removed and examined. The replica shall indicate that the hole bottom is flat within 0.001 in. (0.03 mm)/1/8 in. (3.2 mm) of diameter and roughness shall not be greater than 16 rms finish. For record purposes, the replica may be projected on a comparator screen and photographed as shown in Fig. 2.

9. Checking Ultrasonic Response Characteristics

9.1 All measurements of area-amplitude and distance-amplitude characteristics are to be made using a 5-MHz, 3/8-in. (9.5-mm) flat transducer at a water path distance equal to the measured distance to the last near-field maximum (Y0+) and a previously linearity-calibrated test instrument. Reference blocks that exhibit satisfactory external physical characteristics and proper configuration of the replicated hole shall be subjected to additional examination to check their ultrasonic-response characteristics. If the ultrasonic-response characteristics are to be established by immersion techniques, the drilled

flat-bottom holes shall be cleaned and temporarily plugged by a press-fit TFE-fluorocarbon insert or sealed by some other suitable technique to ensure a leak-tight closure. It is recommended that blocks fabricated as sets be compared with each other to determine their relative ultrasonic-response characteristics. This is particularly desirable in the cases of sets containing flat-bottom holes smaller than 3/64 in. (1.2 mm) in diameter that cannot be satisfactorily replicated.

9.2 *Area/Amplitude Response Curves*—An area/amplitude set may contain several blocks with same external dimensions and distance from the entry surface to the selected FBHs of varying sizes. An area/amplitude-response curve may be obtained by adjusting the examination sensitivity to give a signal with an amplitude of 30 to 40 % of FSD from the block nearest the middle of the range of the reflector sizes. Without changing any examination parameters, the ultrasonic response from the remaining blocks with both smaller and larger size reflectors are plotted on the response curve. A typical area/amplitude curve for a set of 4340 steel blocks is shown in Fig. 3. Any block that exhibits an erratic ultrasonic response and does not



- A—Metal travel distance ± 0.015 in. (0.38 mm)
 B—Hole depth $\frac{3}{4}$ in. nominal $\pm \frac{1}{16}$ in. (1.6 mm)
 C—Block diameter tolerance ± 0.030 in. (0.76 mm)
 2-in. (50.8-mm) diameter for test distances up to 6 in. (152 mm)
 2½-in. (63.5-mm) diameter for test distances over 6 in. up to 12 in. (305 mm)
 Larger diameters or serrations may be required for test distances over 12 in.
 D—Hole diameter tolerance ± 0.0005 in. (0.013 mm) for holes $\frac{1}{16}$ in. (1.6 mm) and smaller, ± 0.001 in. (0.03 mm) for holes larger than $\frac{1}{16}$ in. (1.59 mm)
 E—Surfaces to be flat within 0.0005 in. (0.01 mm) and parallel to within 0.001 in. (0.02 mm).
 Due to possible edge build-up during the plating process, this tolerance applies only to the area exclusive of that within $\frac{1}{8}$ in. (3.2 mm) of the block edges.
 F—Hole must be straight and perpendicular to the test surface within $0^\circ 20$ min.
 G—Hole bottom must be flat within 0.001 in./ $\frac{1}{8}$ in. (1 mm/125 mm) and located within 0.015 in. (0.38 mm) of longitudinal axis.
 H—Flat counterbore 0.250 diameter by 0.064 in. deep.
 I—Typical Block Identification:
 4340 = Typical alloy designation.
 8 = Hole size in $\frac{1}{64}$ -in. increments.
 0300 = Metal travel in 00.00 in.

FIG. 1 Ultrasonic Reference Block Physical Dimensions and Tolerances

fall within the apparent normal area/amplitude-response curve is considered unsatisfactory and shall not be used. Modification of the FBH to meet the required ultrasonic response is not an acceptable procedure.

9.3 Distance/Amplitude Response Curves—A distance/amplitude set may contain a number of blocks with identical dimensions and hole sizes but with varying distances from the entry surface to the FBHs. A distance/amplitude-response curve may be obtained by adjusting the test sensitivity to give a signal with an amplitude of 70 to 80 % of FSD from a block with a distance from the entry surface to the FBH in the lower $\frac{1}{4}$ of the distance range. Without changing any test parameters, the ultrasonic response from the remaining blocks with both shorter and longer distances are plotted on the response curve. A typical distance/amplitude curve for a set of Type AISI 4340 steel blocks is shown in Fig. 4. Any block that exhibits an erratic ultrasonic response and does not fall within the apparent normal distance/amplitude-response curve should be consid-

ered unsatisfactory and shall not be used. Under no circumstances may the FBH be altered to change the ultrasonic-response characteristics of the reference block.

NOTE 4—Because of the resolution obtainable with 5 MHz transducers specified in 9.1 blocks with metal distances of less than 0.500 in. (12.7 mm) may not be able to be checked in accordance with this recommended practice.

9.4 Area/amplitude and distance/amplitude response curves are greatly affected by variations in the configuration of the beam of the search unit, by the near field/far field characteristics and by the horizontal and vertical linearity responses of the test instrument. Therefore, consideration should be given to the operating characteristics of the search unit and instrument (generally available from the equipment manufacturer) when evaluating the response curves from the reference blocks.

9.5 As shown in Figs. 3 and 4, a gain increase may be used to provide more accurate details for blocks with responses of less than about 20 % of full scale.

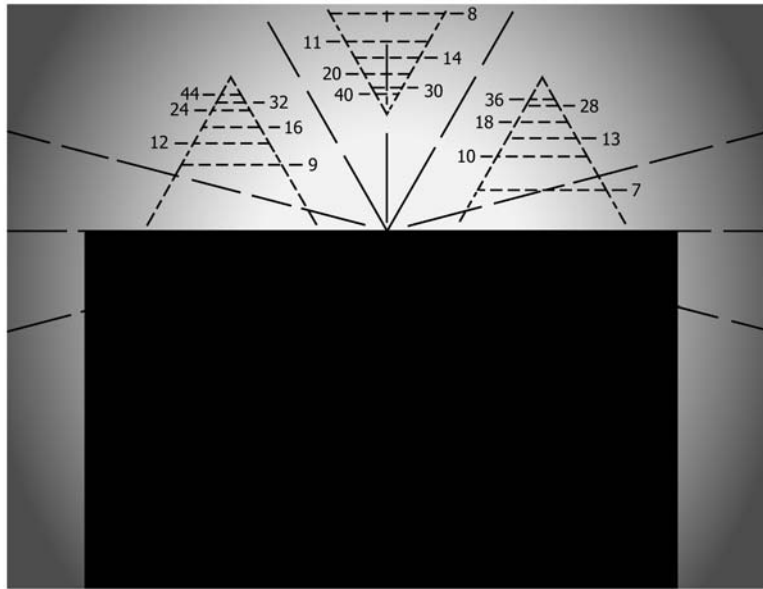
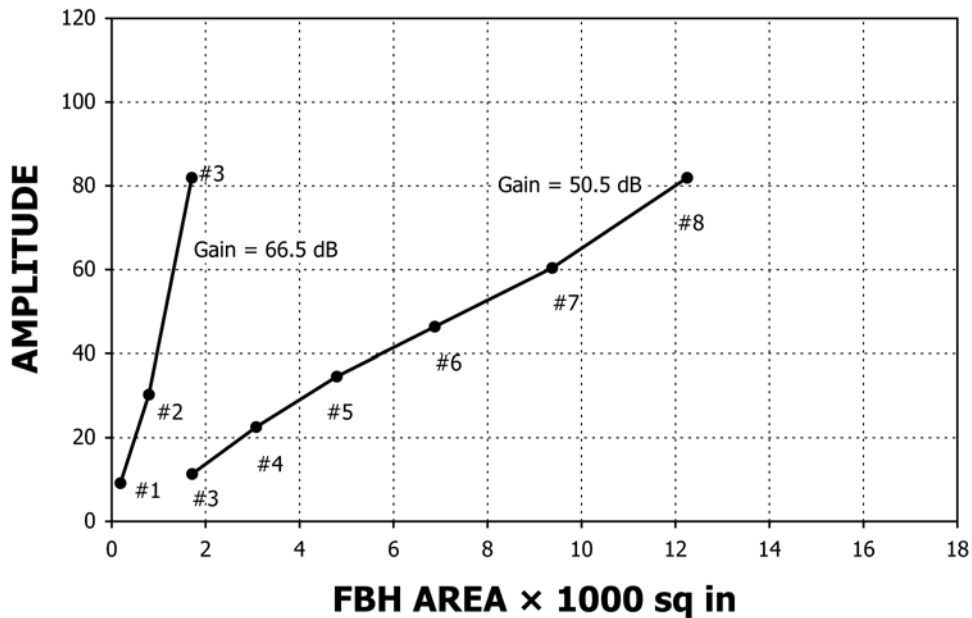


FIG. 2 Shadow-Graph (20x Magnification) of $\frac{1}{64}$ in. (6.4 mm) Diameter Flat-Bottom Hole Replica as Viewed on 62.5x Optical Comparator with Commercial Viewing Screen (Reduced $\frac{1}{2}$)



8 Block Set, 4340 Steel, Flat Bottom Holes
 Transducer: 5 MHz, flat, 3/8" (9.5 mm) Diameter, Water Path = 3.5" (89 mm)

FIG. 3 Typical Area Amplitude Ultrasonic Response Curve

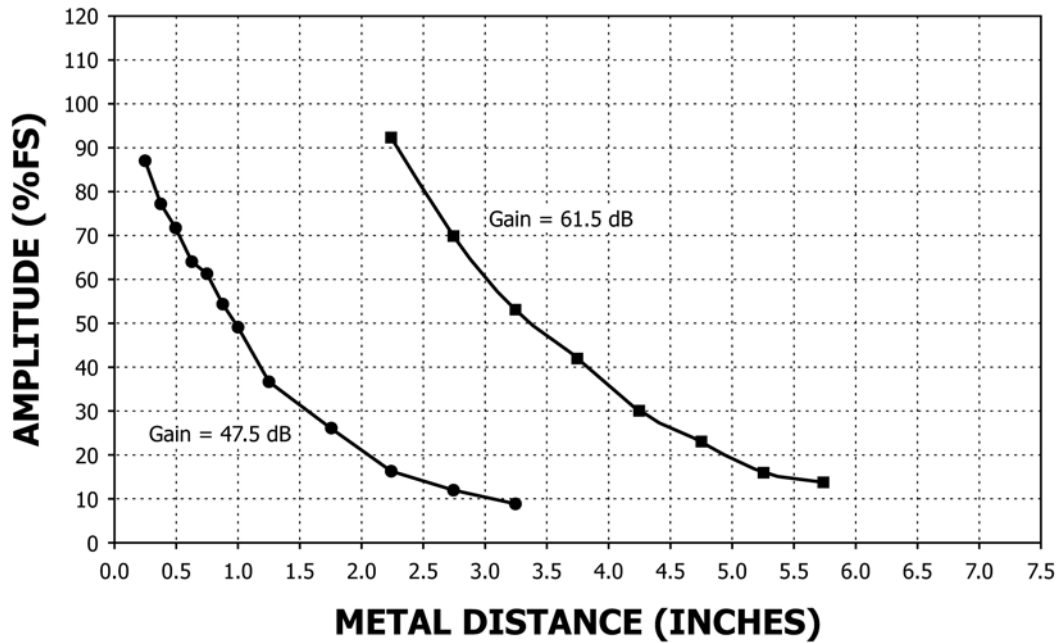
10. Block Identification and Finish

10.1 Reference blocks exhibiting acceptable physical dimensions and ultrasonic-response characteristics may be submitted to the following procedures for identification and application of protective finish:

10.1.1 *Identification*—Each block must be permanently marked (metal stamping or engraving required) with the material AISI alloy or grade, or both, size of the examination hole in $\frac{1}{64}$ -in. (0.4-mm) increments and distance in inches from the entry surface to the FBH. For example, the identification of 4340-5-0300 signifies an AISI 4340 steel reference

block with a $\frac{5}{64}$ -in. (2.0-mm) diameter FBH at a 3-in. (76-mm) distance from the examination surface. Where several sets and types of blocks are being used, a serial number identification must be used. Serial numbers are important when comparing sets of blocks to their respective response curves and to other sets of blocks.

10.1.2 *Protective Finish*—After plugging of the FBHs, a protective coating may be applied to the exterior surfaces of reference blocks fabricated from corrodable-type materials. However, the coating must not significantly affect the physical dimensions or ultrasonic-response characteristics of the blocks.



19 Block Set, 6AL-4V Titanium, 3/64" (1.19 mm) flat bottom holes
 Transducer: 5 MHz, flat, 3/8" (9.5 mm) Diameter, Water Path = 3.5" (89 mm)

FIG. 4 Typical Distance-Amplitude Ultrasonic Response Curve

Generally, nickel plating to a maximum thickness of 0.0008 in. (0.020 mm) is an acceptable coating for carbon and alloy steel blocks which are to be used in a corrosive environment.

11. Plugging Procedure

11.1 Reference blocks that have met the requirements for physical dimensions and ultrasonic response and have been properly identified may be plugged in accordance with the following recommended procedure:

11.1.1 Clean the examination hole with a noncorrosive solvent and dry with a stream of filtered and dried air.

11.1.2 Insert a press-fitted plug (same alloy as reference block) in the counterbore opening as shown in Fig. 1.

11.1.3 Seal the opening by peening the edges of the plug to move the metal outward against the sides of the counterbore.

11.1.4 Grind as needed to blend the back surface and plug to the required tolerances shown in Fig. 1.

11.2 An optional plugging method that may be used on reference blocks fabricated from noncorrodable alloys is as follows:

11.2.1 Clean the examination hole as described in 11.1.1.

11.2.2 Insert a 1/8-in. (3.2-mm) long press-fitted phenolic or TFE-fluorocarbon plug to 1/2 the hole length.

11.2.3 Fill the remainder of the hole with silicone rubber compound or suitable epoxy sealant.

11.2.4 Blend the plug to the back surface as needed. The machined counterbore may be omitted if this plugging technique is used. An adequate air gap must be maintained at the hole bottom.

12. Keywords

12.1 area-amplitude reference blocks; distance-amplitude reference blocks; metal alloy reference blocks; nondestructive testing; ultrasonic reference blocks



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